

Pulsed electron spin resonance on silicon MOSFETs

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Outline

- Motivation – Previous work
- Confined electrons
- Pulsed ESR – T_1 and T_2 results
 - dramatically increased $T_1 = 1.1$ ms at 350 mK
- Conclusions

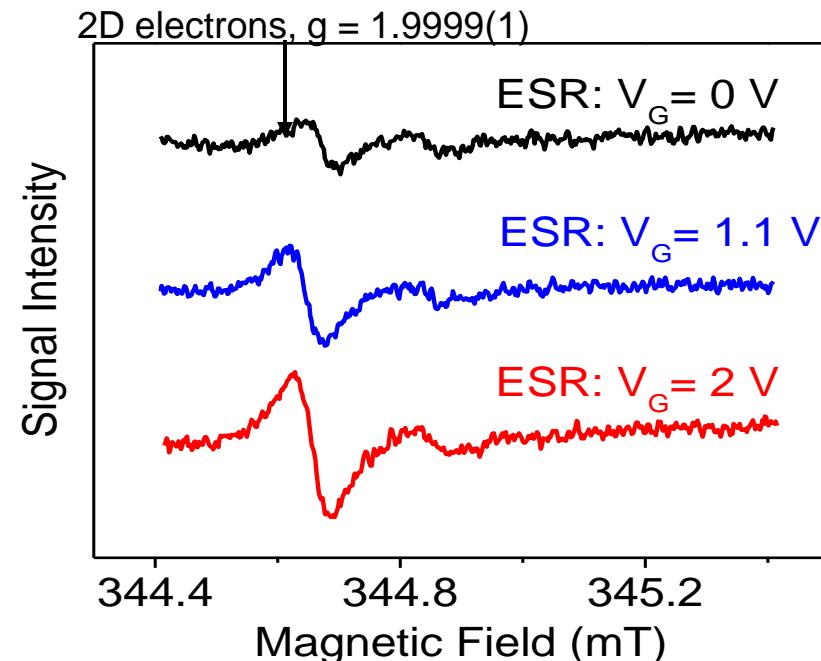
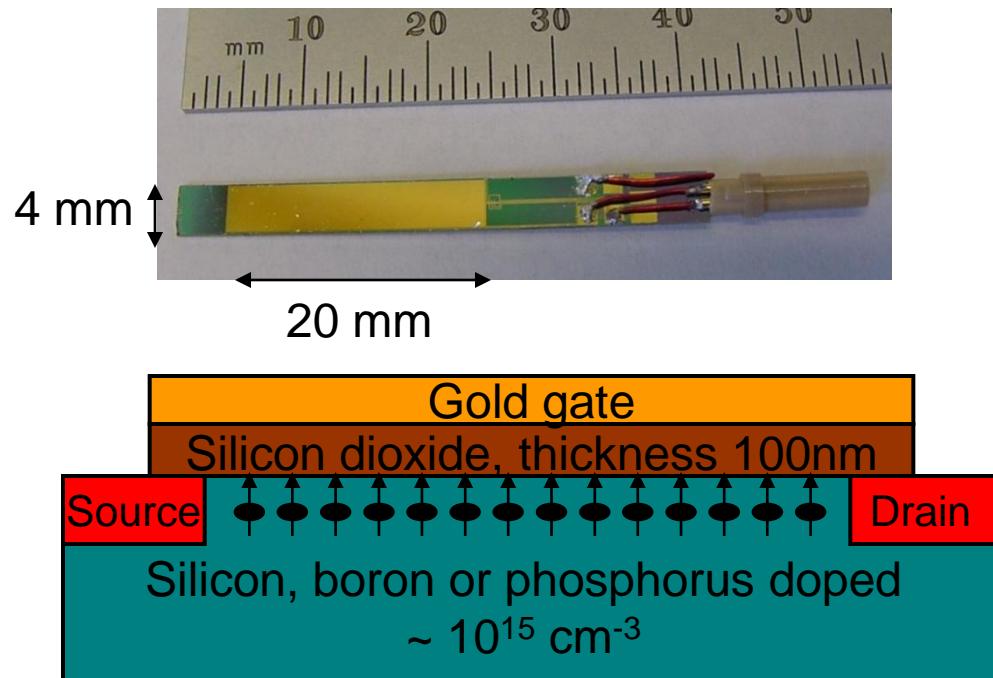


Motivation

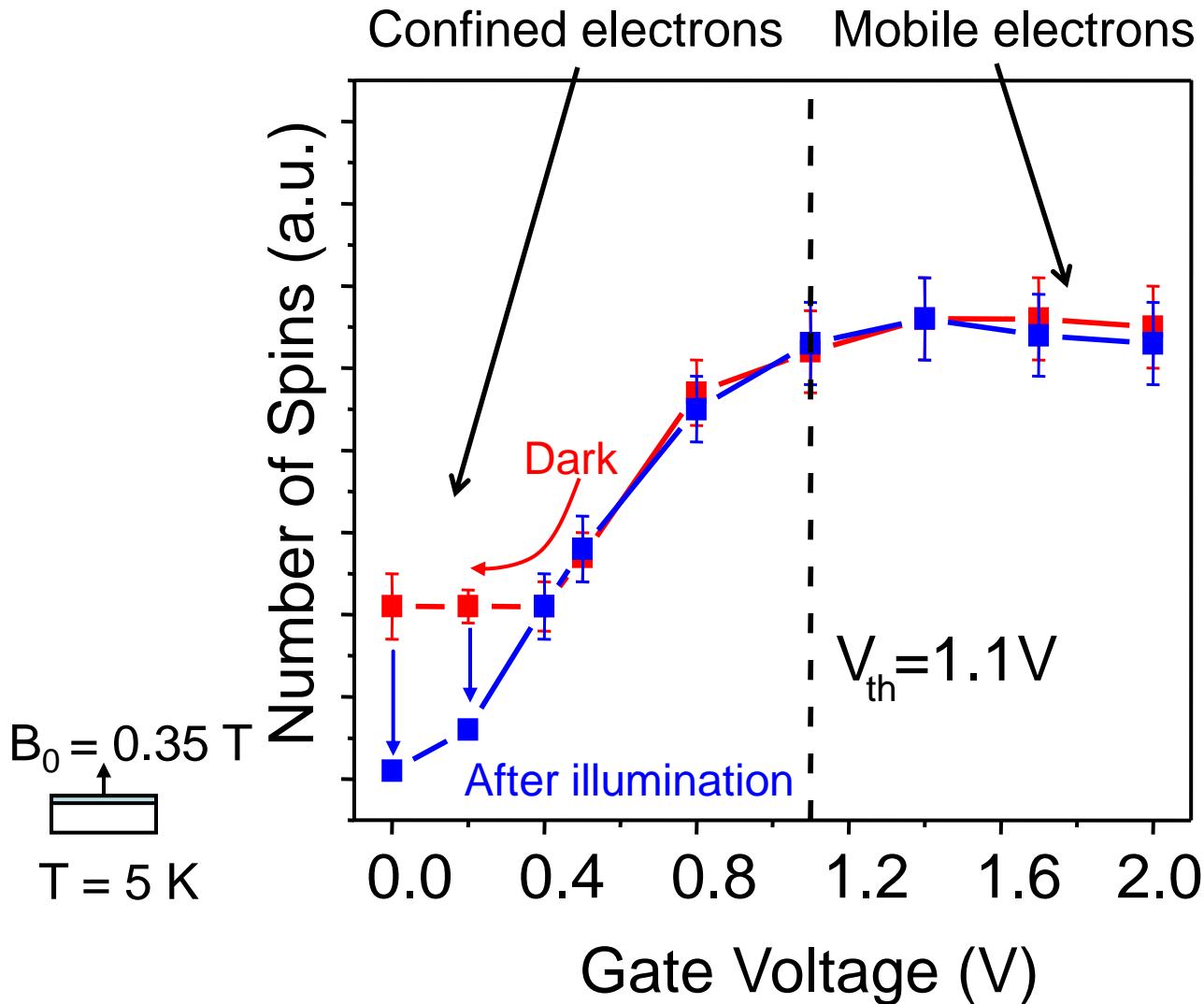
- Free 2D electrons in high mobility Si/SiGe heterostructures
 - $T_1 = 2.3 \mu\text{s}$, $T_2 = 3 \mu\text{s}$ (5 K)
- Electrons tightly bound to phosphorus donors in silicon
 - $T_1 \sim 1 \text{ hour}$, $T_2 = 0.6 \text{ s}$ (4.5 K)
- Recently, quantum dots in Si/SiGe – $T_1 \sim 1 \text{ s}$ (50 mK)
 - arxiv:0908.0173
- Confined electrons – expect long T_1 , T_2
 - energy scale?
 - temperature?
 - relaxation/decoherence mechanisms?

Motivation - Previous work

- Why Si/SiO₂ heterostructure?
 - advantage : good insulator, well developed fabrication technology
 - limitation : traps at the interface, low mobility?
- Previously reported X-band ensemble ESR on large-area silicon MOSFETs (~ 10⁹ unpaired electron spins)



Previous work

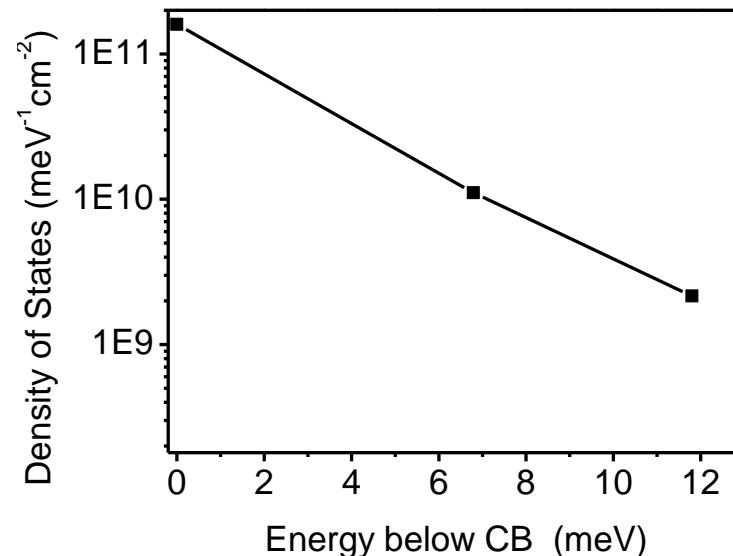
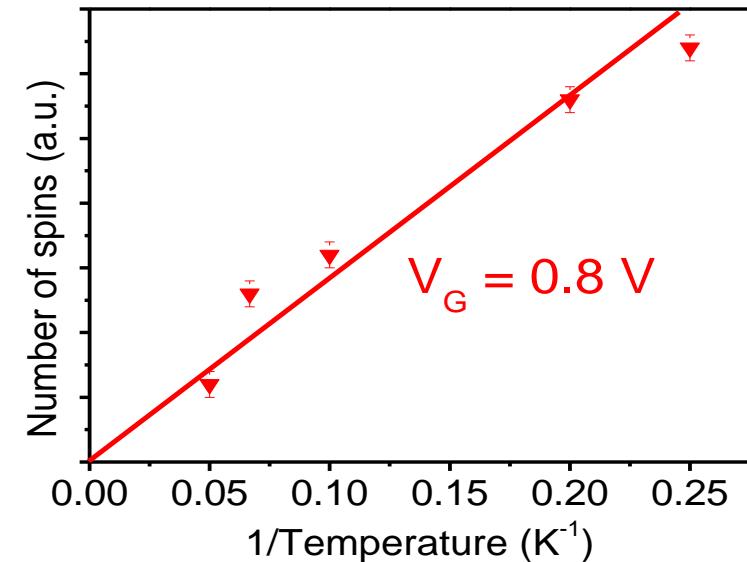
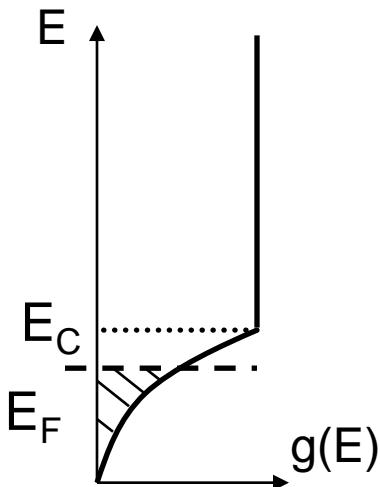


Inversion FET, natural Si

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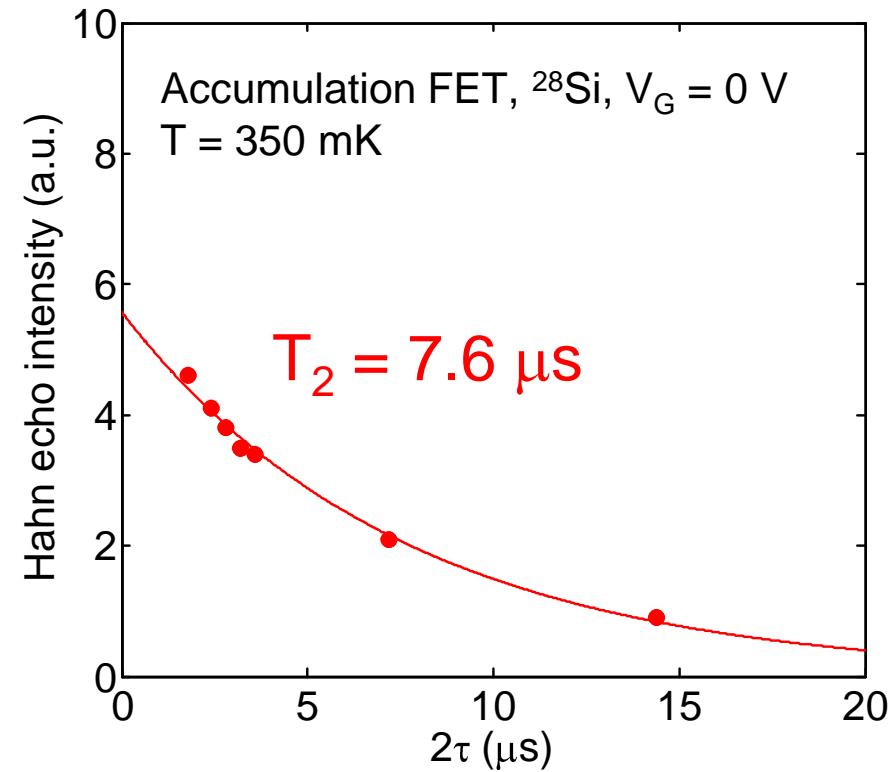
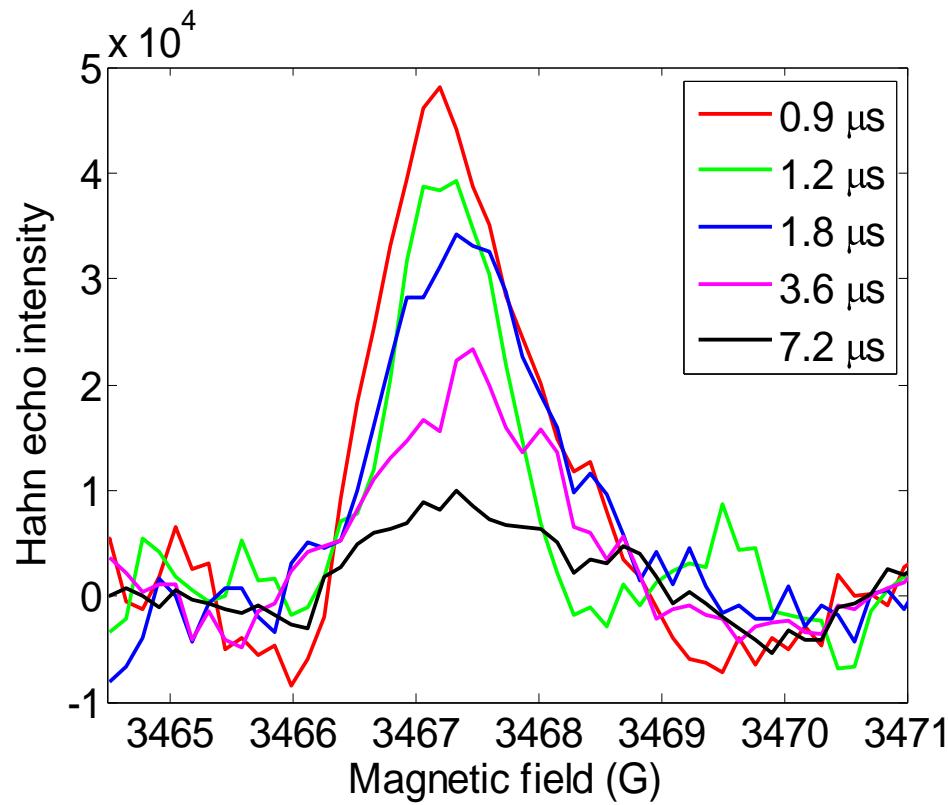
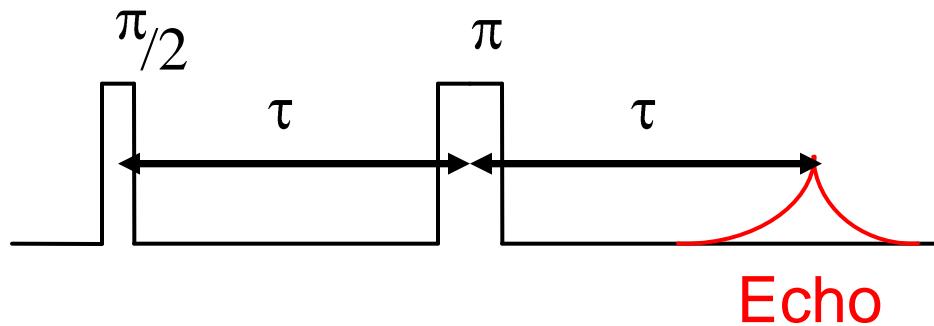
Confined electrons (below V_{th})

- “Natural” quantum dots
 - potential fluctuations from
 - charged traps
 - interface roughness
- Curie susceptibility
- isolated, independent electrons
- Trap depth \sim few meV
- $\sim 10^{10} \text{ cm}^{-2}$ confined electrons



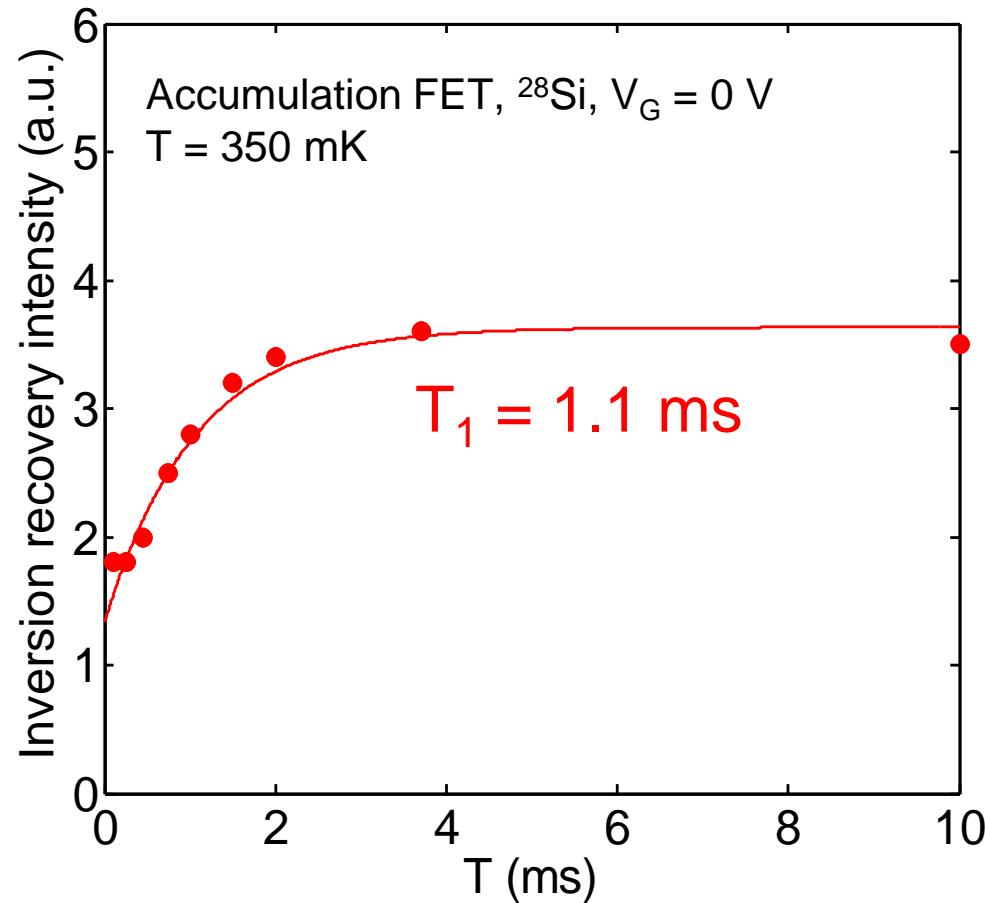
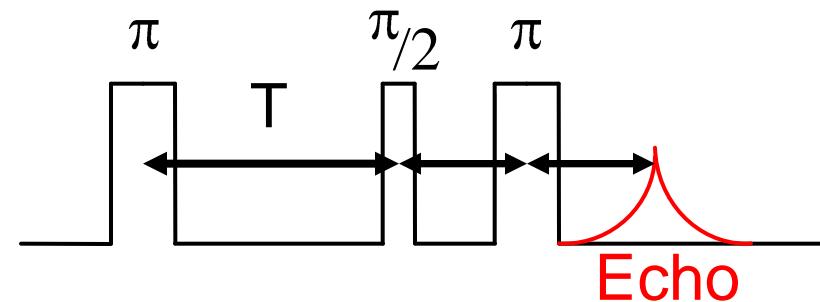
Pulsed ESR – T_1 and T_2 at 350 mK

T_2 - Hahn echo

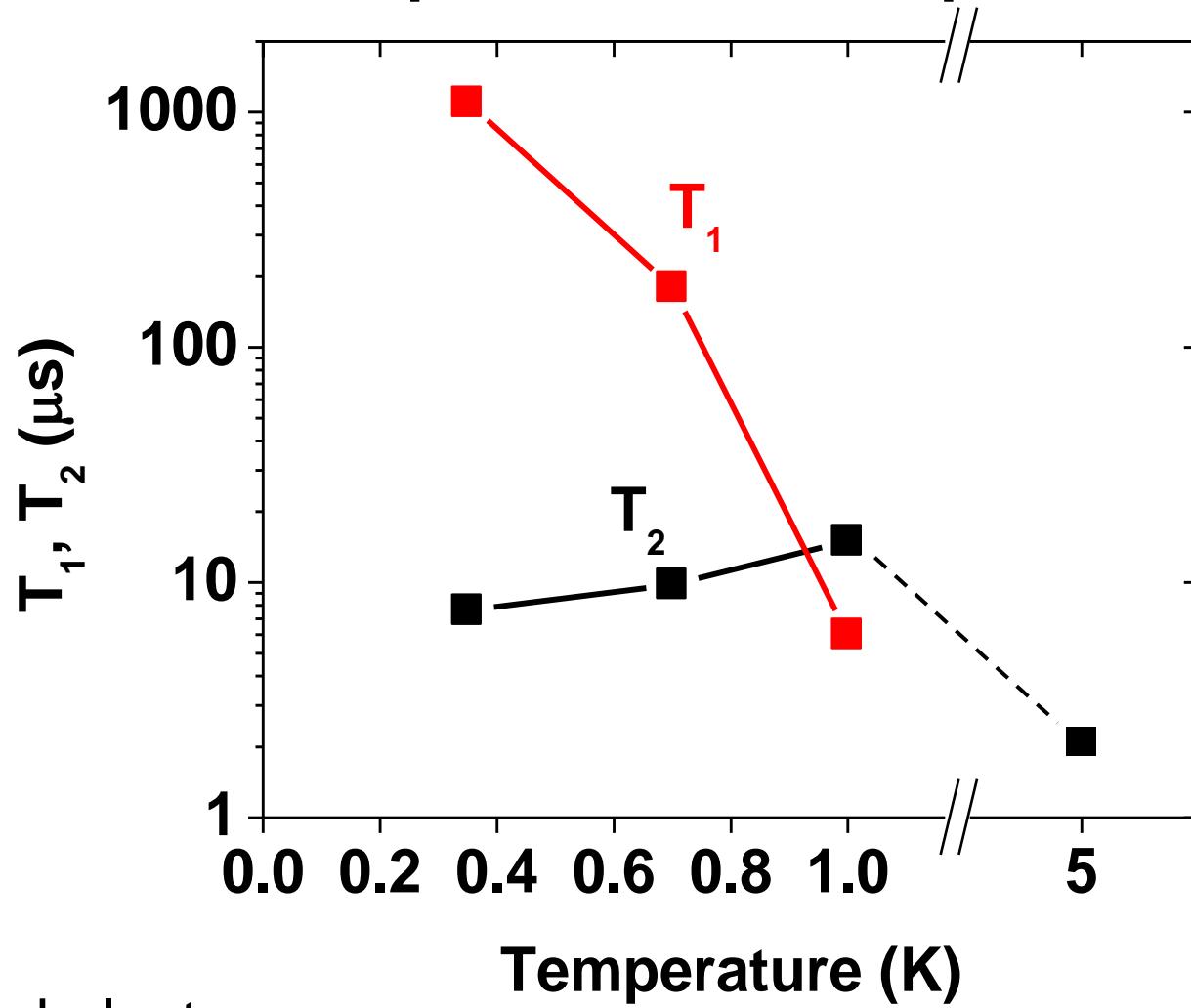


Pulsed ESR – T_1 and T_2 at 350 mK

T_1 – Inversion recovery



Results – temperature dependence



Confined electrons

T_2 – 2.1 μs at 5 K, saturates around 10 μs below 1 K

T_1 rises rapidly - 1.1 ms at 350 mK

Results – gate voltage dependence

V_G	T_1	T_2
0 V (confined) 350 mK 5 K	1.1 ms	7.6 μ s
		2.1 μ s
1 V (threshold) 350 mK	15 μ s	5.7 μ s
2 V (mobile) 5 K	0.32 μ s	0.39 μ s

- Mobile 2D electrons
 - Dyakonov-Perel (Rashba) or Elliot-Yafet mechanism
- Confined electrons
 - T_1 – many orders longer \rightarrow ~ meV confinement reduces relaxation
 - T_2 – does not follow T_1 \rightarrow other decoherence mechanism
 - paramagnetic species, exchange interaction?

Conclusions

- Measured T_1 and T_2 for confined electrons in a silicon MOSFET
 - $T_1 = 1.1 \text{ ms}$, $T_2 \sim 10 \mu\text{s}$ at 350 mK
 - ~ meV confinement dramatically increases T_1
 - T_2 does not follow T_1 . Mechanism still unknown
 - long T_1 promising for spin manipulation experiments in quantum dots in silicon and MOS structures